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Study of beam instabilities in the Fermilab booster at transition

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In order to accommodate high intensity operation, there is a need to understand the instability dynamics of synchrotrons in a strong space charge regime where the transverse space charge tune shift is much greater than the synchrotron tune ($\Delta Q_{sc} \gg Q_s$). Within this regime synchro-betatron sideband modes are significantly shifted by the presence of both space charge forces and wakes. Both wakes and space charge vary along the length of the distribution, making different sections of the bunch such as the core and edges experience qualitatively different average kicks. This difference in coherent forces splits sideband modes and makes new instabilities possible at high intensity. At transition in the Fermilab Booster, a dipole instability of this type can be observed beyond a high intensity threshold. Beam losses are encountered at intensities above 5.4e12 particles per pulse and pose a potential obstacle for the PIP-II era of operation for the Fermilab Booster. This instability is a mixture of a mode coupling instability along with the so-called Convective Instability and has a dipole oscillation amplitude that grows from the longitudinal head of the bunch to its tail.

Footnotes

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